University of Houston

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ANISOTROPIC INSIGHTS FROM PHYSICAL MODELING

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OUTLINE

- Motivation
- Anisotropic sample preparation
- Physical modeling experimental setup
- Results
- Conclusions

MOTIVATION

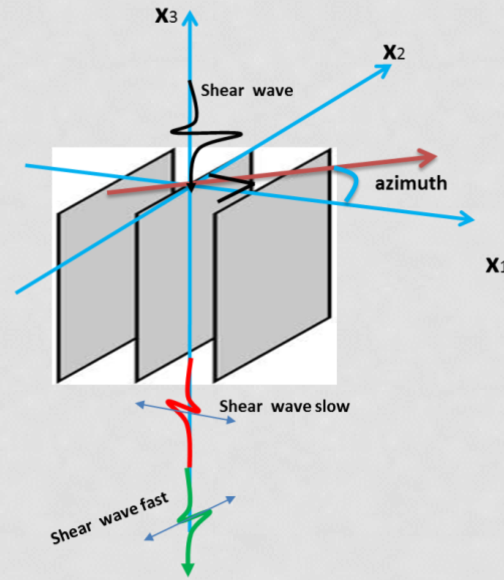
Anisotropic cracked and fractured media shows up different directions of fracture sets

Main theories:

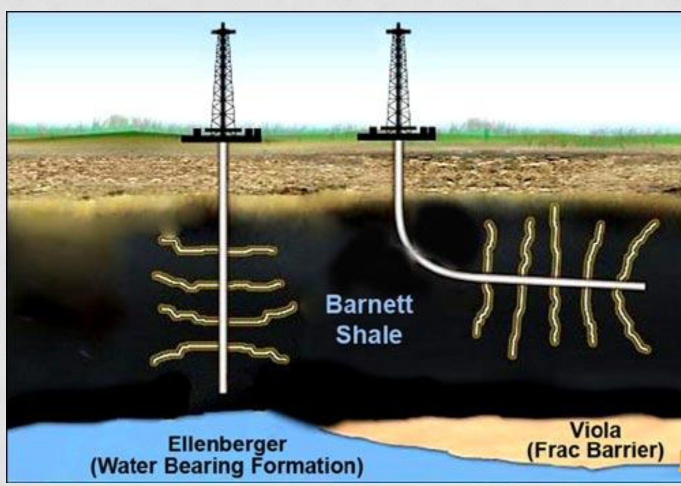
Hudson (1981)

Crampin (1985)

Thomsen (1995)



Olson et al. (2010), The leading edge ,29

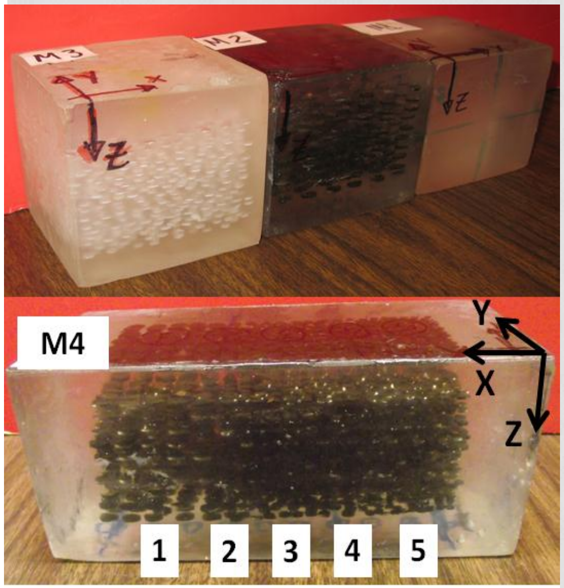


Hydraulic fracturing

http://digitsup.blogspot.com/2011/04/hydraulic-fracturing.html

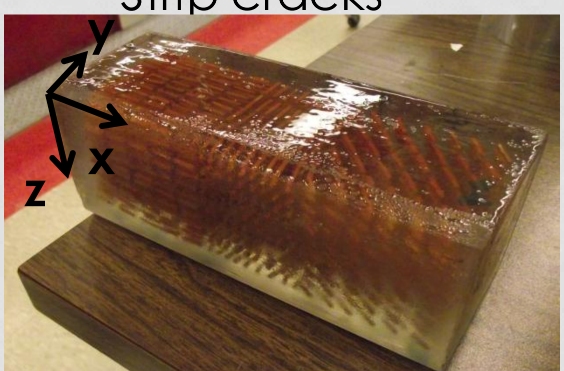
EXPERIMENTAL SETUP-ANISOTROPIC PHYSICAL SAMPLES

Round cracks



Model	Crack density (%)	Measure distance (cm)	Number of Layers	[Diameter] (cm) – [aperture] (cm) of cracks	Number of cracks per layer	Aspect – ratio
M1	Isotropic	7.31 ± 0.02	0	0	0	0
M2	4.5	7.29± 0.02	10	[0.7] - [0.091]	36	0.13
M3	3.8	7.32 ± 0.02	17	[0.4] - [0.051]	90	0.12
M4-1	6.2	7.64 ± 0.02	10	[0.7] - [0.091]	30	0.13
M4-3	5.2	7.74 ± 0.02	10	[0.44] -[0.091]	80	0.20
M4-5	3.8	7.74 ± 0.02	10	[0.32] - [0.091]	100	0.28

Strip cracks



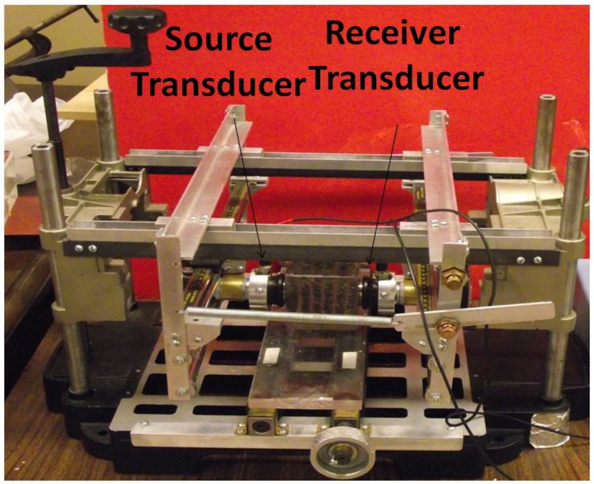
Based on Hudson's theory (1981)

Crack density ➔ $\varepsilon = \frac{Na^3}{V}$

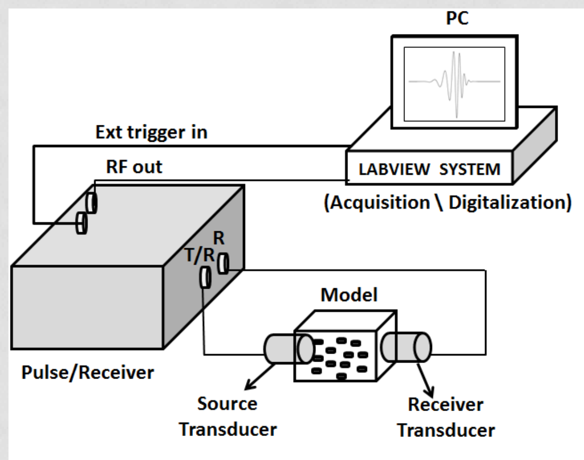
$$N_{cra/lay} = \left(\frac{\varepsilon}{100} * V_{mod}\right) / \left(N_{lay} * V_{cra}\right)$$

Where, $V_{cra} = 3.14 * \left(\frac{d}{2}\right)^2 * h$

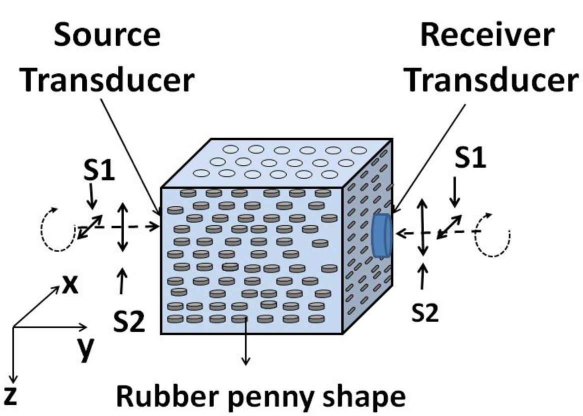
EXPERIMENTAL SETUP -ULTRASONIC MEASUREMENTS

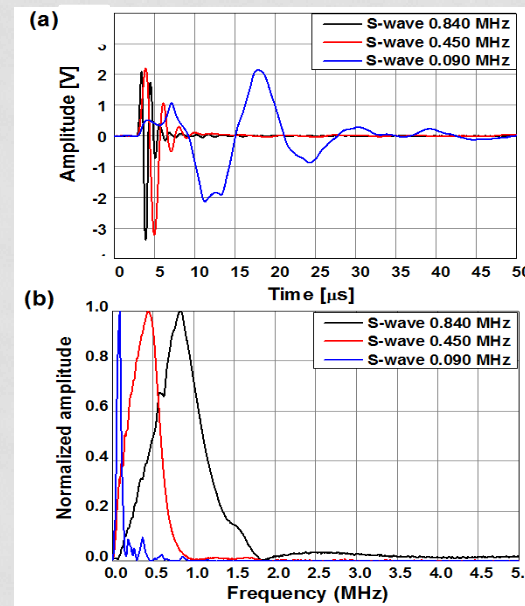


Pulse transmission technique

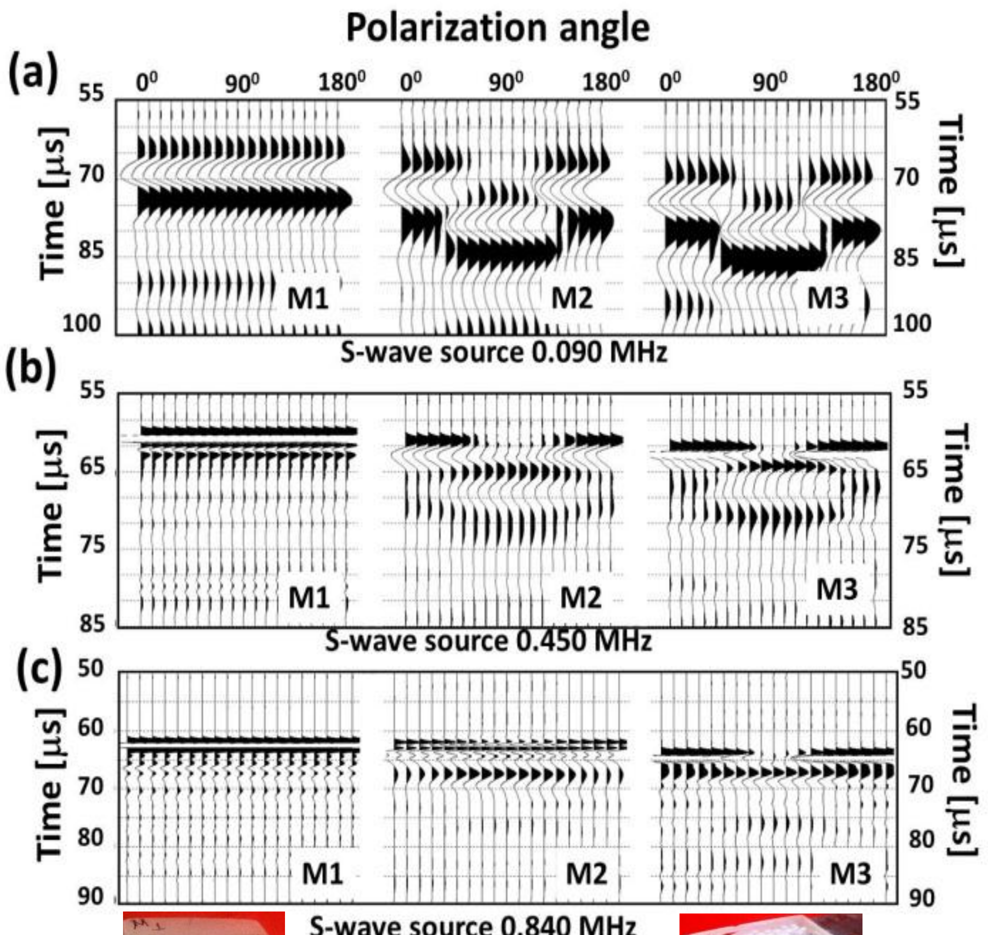


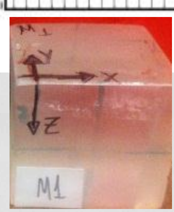
S-waves frequencies sources



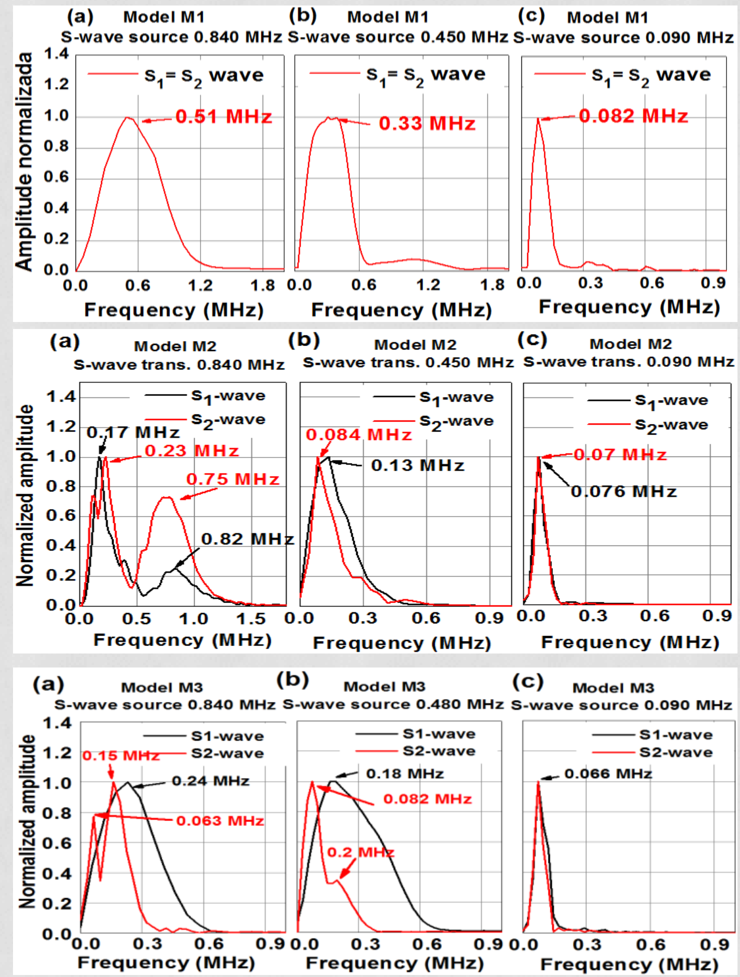


RESULTS AND ANALYSIS

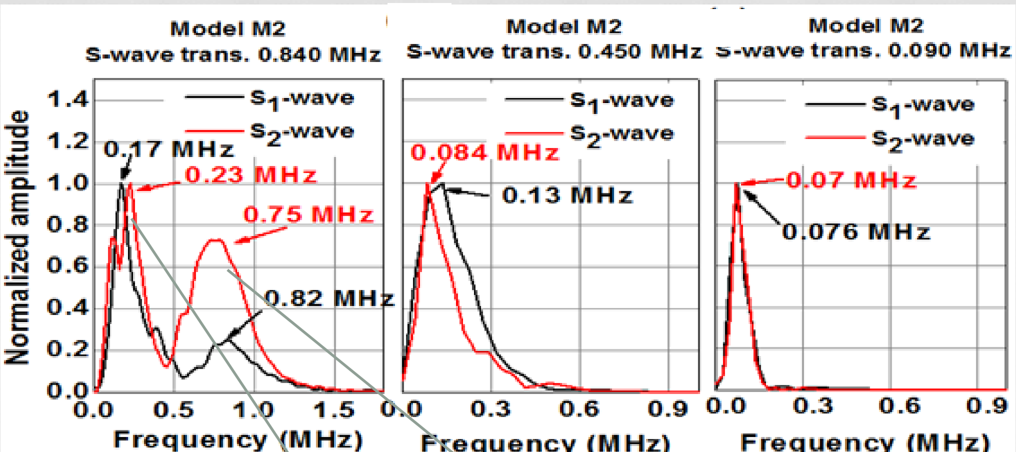




Frequency spectra



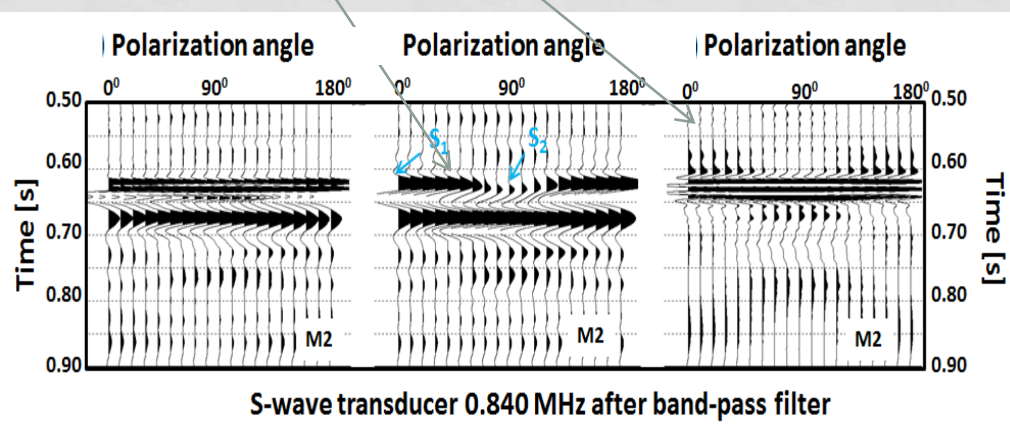
SCATTERING EFFECT

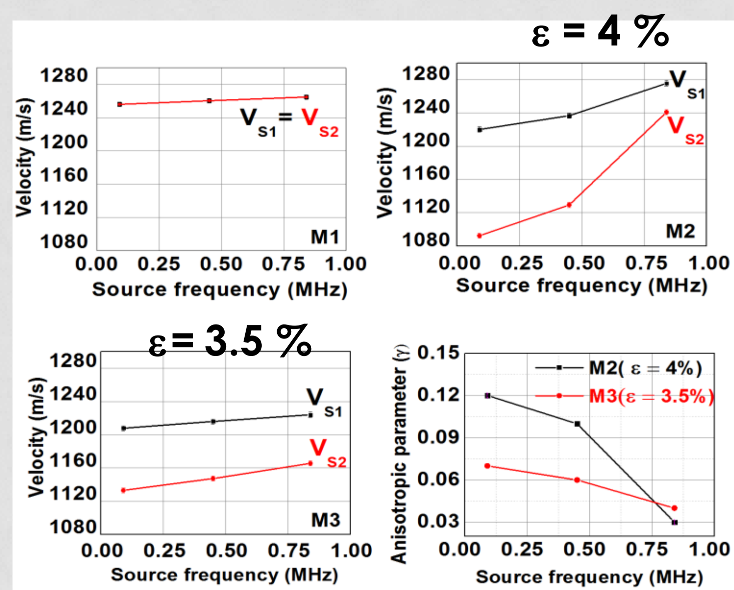


Anisotropic calculation

$$\gamma = \frac{1}{2}\left(\frac{V_{s1}^{\ 2}}{V_{s2}^{\ 2}} - 1\right)$$

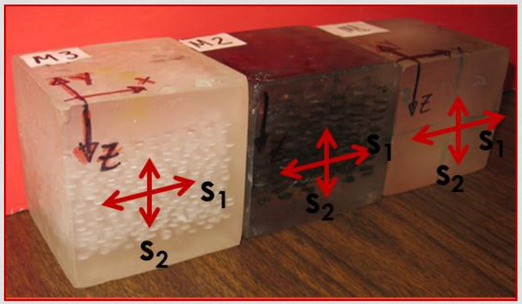
Thomsen, 1986





ATTENUATION ESTIMATION

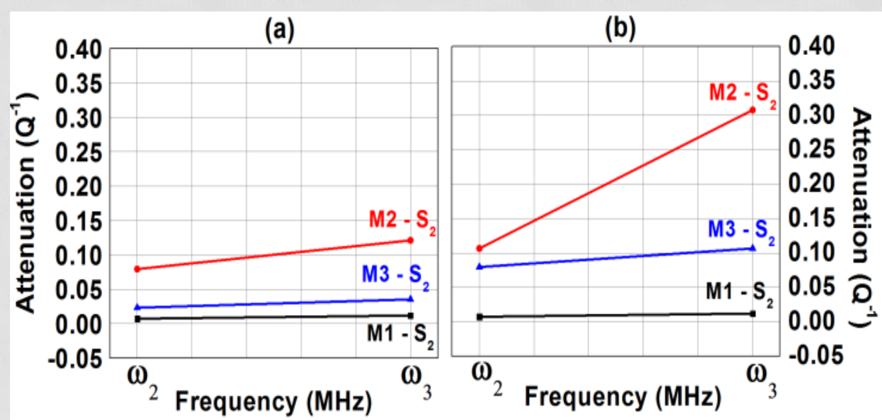
Attenuation Q^{-1} for models M1, M2 and M3 respectively for the shear-wave polarizations S_1 and S_2.



	Frequencies(MHz)			Shift-time (ms)	
Model	w1(S1,S2)	w2(S1,S2)	w3(S1,S2)	|t(w3)- t(w1)| (S1,S2)	|t(w2)-t(w1)| (S1,S2)
M1	(0.082,0.082)	(0.377,0.377)	(0.514,0.514)	(0.4,0.4)	(0.2,0.2)
M2	(0.076,0.07)	(0.13,0.18)	(0.17,0.24)	(1.8,7.2)	(0.8,5.0)
M3	(0.073,0.067)	(0.18,0.08)	(0.24,0.156)	(0.8,1.8)	(0.4,0.7)

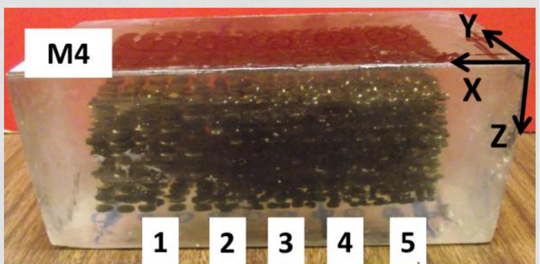
Applying Drift-time correction method (Stewart et al. ,1984)

$$t_{delay} = \frac{l \ln\left(w_j / w_i\right)}{\pi Q V(w_j)}$$



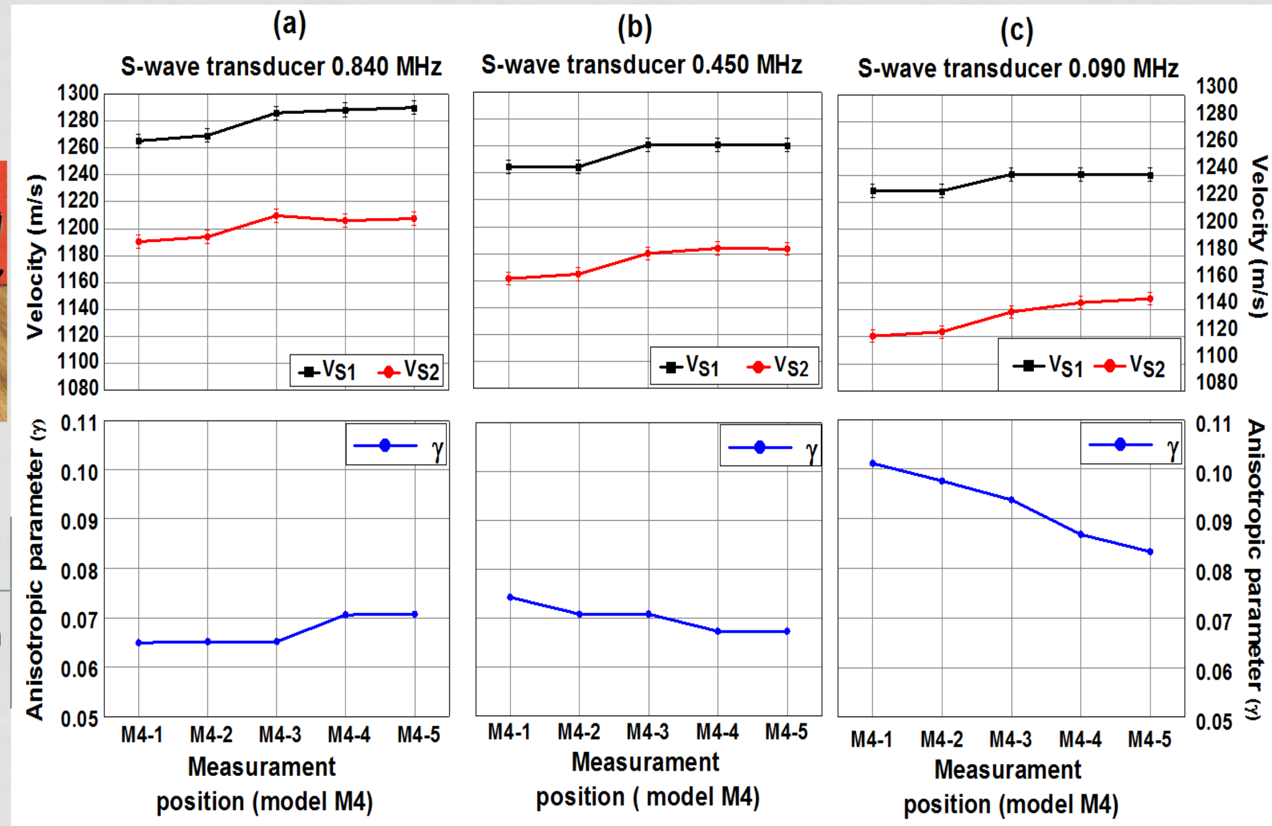
SIZE EFFECT- ANISOTROPIC PARAMETER

Shear wave velocity and anisotropic parameter γ

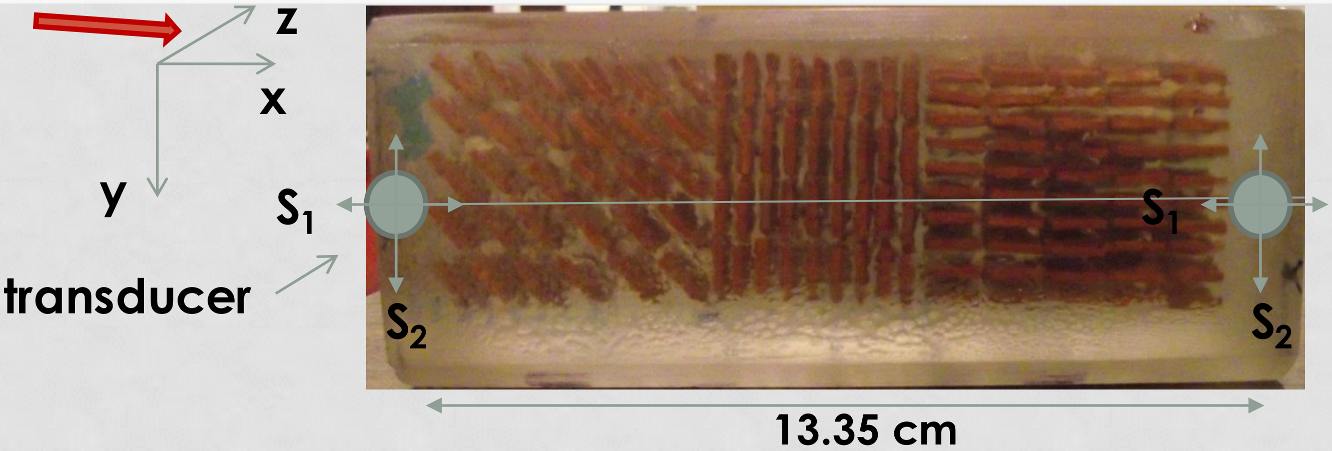


(b)

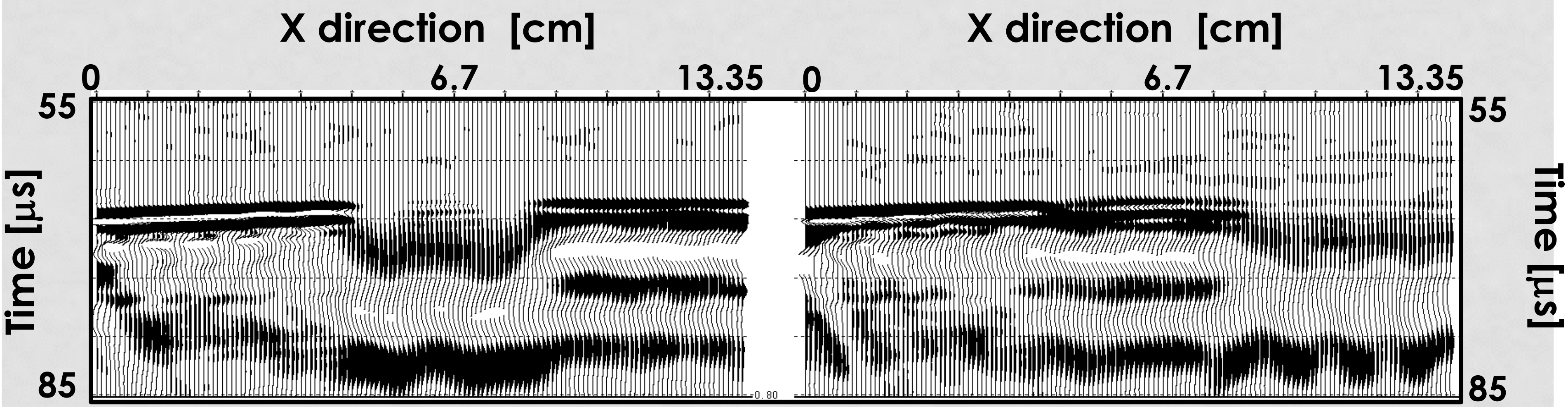
diameter	0.7 cm	0.44 cm	0.32 cm
crack density	6.2 %	5.2 %cm	3.8 % cm



HIGH FREQUENCY: FRACTURES DIRECTIONS



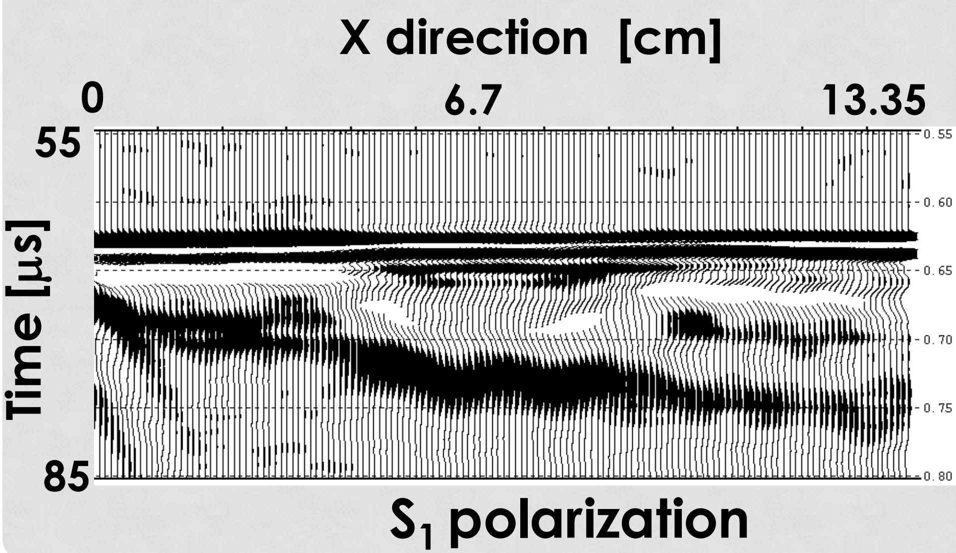
Common-offset transmission setup

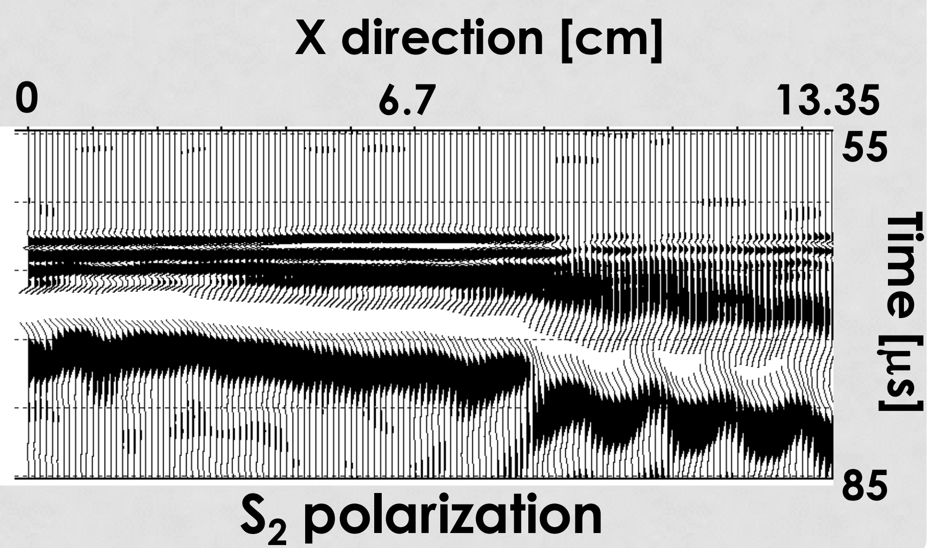


S_1 polarization

S_2 polarization

HIGH FREQUENCY -FRACTURES DIRECTIONS





CONCLUSIONS

- Anisotropic parameter is influenced by relations between frequency source and crack densities.
- Shear-wave splitting has direct relation with:

  Dispersion

  Size of inclusions and aperture

  Apparent attenuation
- High frequency range can lead to important information about fracture reservoir management.

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